

# Improved Barrier Coatings on Flexible Ribbon Cables for Long-Term Biomedical Implants

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## ABSTRACT

Over the last decade, the biomedical research community has been searching for reliable methods to interconnect sensors to instrumentation systems. These interconnects must be very small and flexible. For implantable applications, they must survive attack by harsh ionic fluids and immune defenses. In this project, we are investigating the ability of flexible, polyimide ribbon cables to meet these stringent requirements. We have developed an interdigitated electrode (IDE) array test structure suitable for soak testing. A series of first generation samples with polyimide insulating layers of varying thickness were fabricated using our routine insulating methods in the Spring of 1998 and sent to MIT where they have been soaked in saline at 37 °C. One combination of materials (5 mil Kapton®, gold conductors, and 15 micron spin-on polyimide) is still performing well with impedance levels remaining above  $10^{11}$  Ohms for all four samples devices. Now that the feasibility of fabricating flexible ribbon cables for implantable applications has been demonstrated, we are investigating improved barrier coatings to increase the lifetime of the existing samples, and to enable us to fabricate thinner, more flexible devices. Tribofilm Research has developed an amorphous diamond-like carbon (DLC) coating that has excellent water vapor barrier properties. We are currently fabricating various multilayer insulating barriers with spin-on polyimide and amorphous DLC layers. Accelerated life testing is being performed on these films and preliminary results will be presented at the Workshop.

## **SUMMARY**

### **Medical Applications for Flexible Ribbon Cables**

For many years, the biomedical research community has been searching for reliable methods to interconnect sensors to instrumentation systems. Small, flexible ribbon cables that resist penetration ionic fluids and immune defenses have not yet been developed. Such cables are highly desirable for biomedical research undertaken by NASA and NIH. A testing facility at MIT has been established by the NIH Neural Prosthesis Program to screen insulating biocompatible materials. In this project, we are investigating new material combinations to find a solution to the implanted interconnect problems.

### **First Generation Samples**

Figure 1 depicts an interdigitated electrode array test structure that we have designed for testing insulating materials for flexible ribbon cables. These structures are coated with various insulating layers and then soaked in saline until they fail (short-circuit). In June 1998, we began testing the first generation of our test structures. Five batches of devices were fabricated on 5-mil Kapton®, each insulated with a different barrier coating. Four identical samples were produced in each batch:

- 1) Dow Silicone T-RTV
- 2) Dow 3-1753
- 3) Dupont PC-1025
- 4) Dupont PI-2723
- 5) Dupont PI-2721

### **Results of Laboratory Soak Tests**

The first four barrier coating types failed within a month initiating the test. The fifth one however continues to perform as is shown in Figure 2. Note that all four of the devices in this batch are exhibiting impedance levels of  $10^{11}$  Ohms or higher. If the devices continue to perform as expected, they should fail at 0.8 to 1.0 years.

These results are very encouraging since we took no special measures to enhance the water vapor barrier properties of the insulating films. We expect that the lifetime of these insulating materials can be greatly enhanced by employing thin amorphous diamond like carbon (DLC) in layers with the spin-on polyimide coatings.

### **Properties of Amorphous DLC Films**

Tribofilm Research, Inc., of Raleigh, NC, has developed DLC coatings that are deposited by Plasma Enhanced Chemical Vapor Deposition (PECVD). PECVD is a near room temperature process that facilitates the modification of temperature sensitive polymeric materials. Plasma polymer coatings are highly crosslinked and amorphous in nature. X-ray diffraction studies have

been used to show the complete absence of crystalline phases in these films [1], and the crosslinked nature of the films has been substantiated by the inability of conventional organic solvents to dissolve both plasma polymer films and powders. Infrared spectra of plasma polymers contain broad, overlapping bands which are indicative of their complex stoichiometry, high degree of crosslinking and amorphous nature [2].

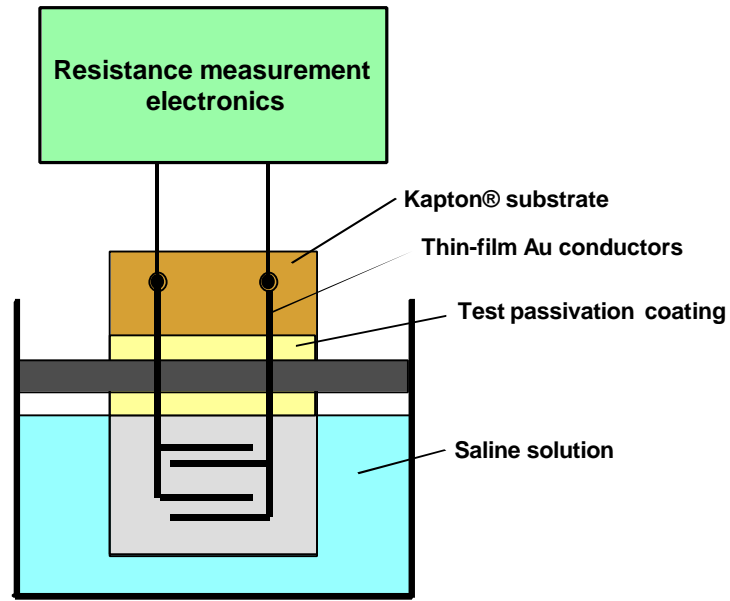
Tribofilm DLC barrier coatings are thin (approximately 3000 angstroms), flexible and chemically bonded to the polymer substrate. Figure 3 shows the results of water vapor diffusion through coated and uncoated 2 mil polyethylene terephthalate films. These results are for single layer coatings on PET substrates coated on one side and measured at 38 °C. We expect improved barrier performance with our composite multilayer coating structure consisting of alternating layers of polyimide and DLC applied to both sides of the Kapton® substrate.

### **Current Activities**

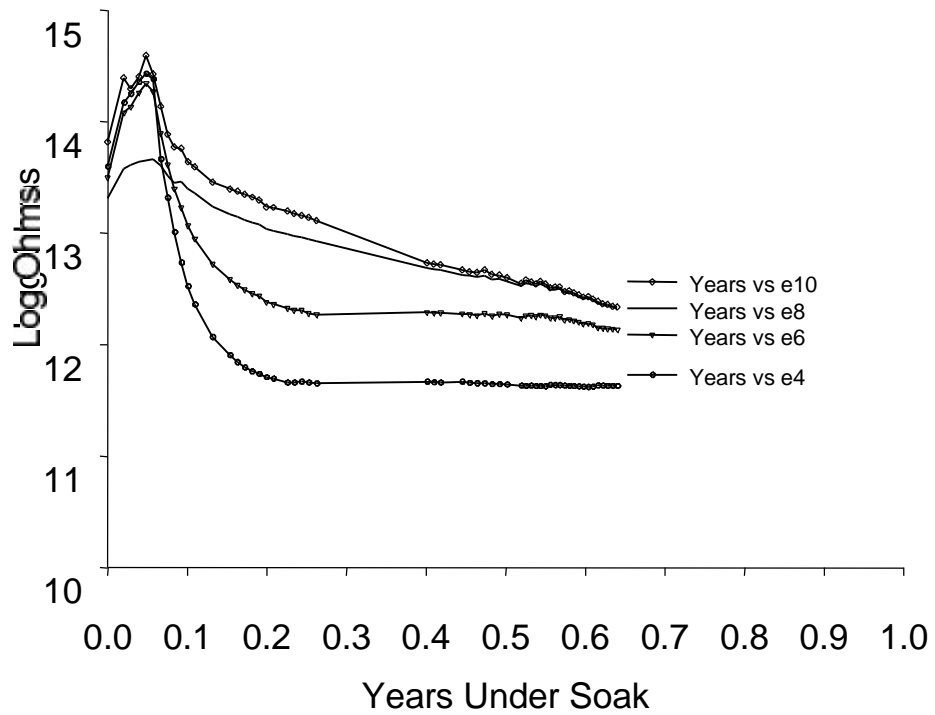
Multilayered composite coatings consisting of alternating layers of DLC and polyimide are being deposited on both sides of the metal conductors. These second generation samples will first be subjected to accelerated life tests in North Carolina for stability under saline environments at 60 degrees C. Combinations that survive for two weeks or more will be reproduced and sent to MIT for their standard soak testing experiments. The results of these new tests will be reported at the Workshop in June.

### **References**

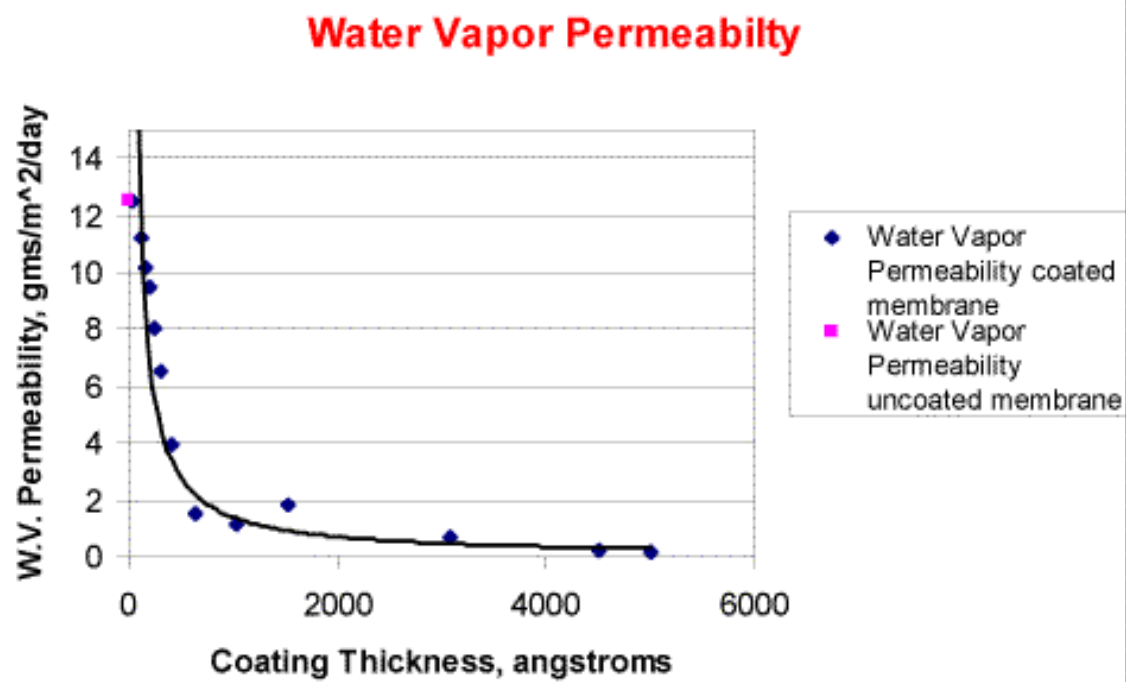
1. H. Kobayashi, A.T. Bell, and M. Shen, (1973) *Journal of Applied Polymer Science*, 18, pg 885.
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**Figure 1. Kapton® Test Structure.**



**Figure 2. Initial Soak-Test Results.**



**Figure 3. Water Vapor Permeability of DLC Barrier Coatings.**